ECONOMIC TRANSFORMATION:

Technological Innovation and Diffusion in Ontario

Ontario

The Honourable Larry Grossman, Q.C.
Treasurer of Ontario
and
Minister of Economics

March 1984

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PREFACE

Last December, an Autumn Pre-Budget Statement was released to open up the process of consultation. That paper detailed the transformation taking place in the economy and set the stage for discussions on policies to guide and advance economic transition.

This document, "Economic Transformation: Technological Innovation and Diffusion in Ontario", is one of a series of papers to be issued by the Ministry of Treasury and Economics. It outlines the importance of innovation and widespread application of new technologies to the process of economic transformation, and presents data and analysis to encourage a full exchange of information and ideas. It also presents some policy options to be considered as we seek to encourage technological innovation and diffusion.

You are invited to forward your comments and suggestions to me at the address listed below. I hope you will do so.

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Table of Contents

I INTRODUCTION

An economic transformation based on technological innovation is underway in Ontario and Canada. The rapid commercialization of inventions and the adoption by industry of product and process innovations will have a significant impact on the structure and competitiveness of the economy in the next decade. Recent advances in microelectronics, communications technology, computer-aided design and manufacturing, robotics, information processing, special materials and biotechnology are at the forefront of this technological transformation. Advances in scientific knowledge and progress in its technological application play a considerable role in economic growth. The pace of this progress, however, is influenced by the many other factors which affect national economic performance, from interest rates to education policies to factors such as market and firm size.

Canada's strength in international trade has traditionally been in resources and resource-based manufacturing. While Canada has experienced substantial trade surpluses in these areas, there have been trade deficits in finished manufactured goods, particularly innovative or high-technology products. Recently, however, slow growth in world demand combined with increased competition from developing countries has adversely affected Canada's traditional exports. In recent years, the fastest growing components of world trade have been standard-technology manufactured goods from less developed nations and high-technology products from advanced industrialized countries. Further shifts in international demand toward technology-intensive products are expected. If Canada is to maximize future economic growth and to raise living standards through increased trade, we must strengthen our high-technology manufacturing and service sectors.

Activity in the Canadian and Ontario economies has already begun to shift toward knowledge-intensive industries. This shift is demonstrated by the relatively fast growth of the high-technology manufacturing and service industries. These sectors, characterized by continuous innovation, provide many highly-skilled jobs. The high-technology manufacturing sector generates larger productivity increases and substantially lower price increases than manufacturing generally.

The continued development of a vital innovative sector will be an important factor in economic growth. However, it is unlikely that Canada will become competitive in all high-technology fields. Moreover, resources and less-technology-intensive manufacturing and services will continue to supply the greatest proportion of new jobs, output and exports. Yet even in these sectors, Canada faces a period of increased international competition from low-wage countries and from developed nations using new management and production techniques. As a high-wage country, Canada's international competitiveness will depend not only on creating new technology-based industries but also on diffusing current technologies throughout existing industries. The greater the opportunity to use new labour skills and knowledge in resource extraction, manufacturing and services, the more sustainable will be Canada's future competitiveness.

Government concern with technology development in recent years has been largely directed towards encouraging innovation through financial incentives for research and development. A paper released with the 1983 Ontario Budget, "R&D and Economic Development in Ontario: A Discussion Paper", showed that tax-based support for R&D in Canada is already the highest among advanced industrialized countries, and that other factors are contributing to lower R&D performance in Canada.

The focus of policy concern in Ontario is being moved downstream from R&D, to encourage the process of innovation -- the commercialization of research results -- as well as the adoption of new technologies by existing industries.

The next section of this paper addresses Canada's innovation performance in an international context and examines the high-tech sectors in Ontario and Canada. The third section looks at the importance of technological diffusion to the Canadian economy and deals with the evidence on adoption lags in Canada. The policy-related factors that affect our innovation record and diffusion speed are discussed in the fourth section. The fifth section of the paper examines government policies for facilitating economic transformation and suggests future policy directions.

II THE ROLE OF INNOVATION IN ECONOMIC TRANSFORMATION

Innovation is defined as the activities required for the successful introduction, on a commercial scale, of a new or improved product, process, system or service. These activities include design and engineering, and manufacturing and marketing start-up. The term innovation also refers to the new product or process itself. While the economy benefits greatly from many organizational or non-technological innovations, such as shopping centres, multi-divisional management or just-in-time inventory control, this paper focuses on innovations in product and process technology, and their widespread adoption by industry.

Canada's innovation record does not match those of other industrial countries. International comparisons, however, give only an overall indication of innovative performance. Canada is already internationally competitive in a number of innovative products and services. A shift towards these industries is now underway and the rapid growth expected in these sectors will result in an increasing share of output resulting from innovative activities over the next 20 years.

Innovation in an International Context

Canada does not fare well in international comparisons of innovative activity. A survey of the 500 most important innovations introduced in six countries between 1953 and 1973 indicated that Canada launched eight. This was only 1.6 per cent of the total, although Canada had 4.1 per cent of the total population of these countries. The strength of post-war innovation in the United States and the United Kingdom is demonstrated in Table 1. During this period, Japan concentrated on imitating and improving foreign innovations and therefore showed a poorer per capita level of original innovation than Canada. Recently, Japan has concentrated more heavily on innovation, but Canada has not.

DISTRIBUTION OF KEY POST-WAR INNOVATIONS AND POPULATION BY COUNTRY
(per cent of total)

Table 1

	Innovations 1953-1973	Population 1963
United States	63.8	40.8
United Kingdom	17.0	11.6
Japan	6.8	20.9
Germany	6.6	12.4
France	4.2	10.3
Canada	1.6	4.1
Total	100.0	100.0

Note: Columns may not sum due to rounding.

Sources: Gellman Research Associates, Inc. , Indicators of International Trends in Technological Innovation, a report prepared for the National Science Foundation, 1976; United Nations, Monthly Bulletin of Statistics, 1973.

An indicator of inventiveness, though not necessarily of innovation, is the number of patents issued. Despite the common contention that Canada invents new products but is unable to commercialize them successfully, international patent statistics indicate that Canada has played a relatively small role in invention. Between 1972 and 1978, for every 100,000 persons in the labour force, an average of 14 Canadian patents for Canadian inventions were issued, compared to 49 American patents for American inventions[1]. The patent data are consistent with the results of the study of the 500 most important innovations. Patents granted in the United States by country of patentee over the 1973 to 1982 period show a pattern similar to the distribution of innovations among the six countries in Table 1.

International comparisons of R&D expenditure as a proportion of GNP provide indirect evidence on relative innovation performance. Canadian expenditures on R&D are estimated to have been nearly 1.3 per cent of GNP in 1983, lagging well behind the performance of Canada's major industrial competitors.

1 Statistics Canada, Canadian Science Indicators, 1983, p. 79.

Canada's relatively poor innovation performance reflects a number of factors. Part of the difference can be explained by proportionately lower defence-related R&D expenditures in Canada than in most other OECD countries. Innovation in Canada is also affected by market size, degree of foreign ownership, supply of venture capital and availability of skilled personnel. Finally, Canada's innovation performance reflects its industrial make-up. Unlike other industrial countries, a large part of the Canadian economy consists of industries that, by their nature, contribute relatively few innovations to the total. For example, in all countries, resource and resource-processing industries afford fewer opportunities for technological innovation than do engineering-based manufacturing industries.

Innovation and Economic Transformation

Although Canada has produced relatively few of the world's innovations, many Canadian firms have successfully introduced important new products and processes. For example, Canadian resource firms have innovated to maintain their international competitiveness. Knowledge-intensive activities, particularly in the high-tech manufacturing and service sectors, are becoming increasingly important. The rapid growth of these sectors is contributing to the transformation of the economy.

Resources and Resource-based Manufacturing

World-scale Canadian resource firms have responded to rising costs, erratic prices and increased international competition by increasing productivity through the use of new methods and improved machinery. Major mining companies have invented more productive extraction techniques, and are moving into manufacturing operations where they are actively developing new alloys and processes. An indication of the growing importance attached to innovation in resource firms is the recent formation of a corporation by several Ontario-based mining companies to undertake joint research programs.

A greater proportion of industrial R&D takes place in the Canadian mining sector than in the mining sectors of other OECD countries. Canada's

R&D is becoming even more resource-oriented as a result of growth in the energy sector and in energy-related R&D. The significant role of resource sectors in Canadian innovation can be illustrated by Canadian patent information. Of the top ten Canadian patent-receiving organizations in 1981, five are resource-oriented.

TOP TEN CANADIAN PATENTEES FOR CANADIAN INVENTIONS, 1981 — Table 2

Patentee	Industry	No. of Patents
Northern Telecom	Electronics	over 50
National Defence	Government	20-50
Canadian General Electric	Electrical products	20-50
Imperial Oil	Oil extraction and refining	10-19
Polysar	Chemicals and rubber	10-19
Sherritt Gordon Mines	Mining and smelting	10-19
Inco Limited	Mining and smelting	10-19
Alcan	Aluminum smelting, fabrication	10-19
Canadian Patents & Development	Patent development organization	10-19
Cominco	Mining and smelting	10-19

Source: Statistics Canada, Canadian Science Indicators, 1983.

Service Industries

Technological innovation in the service sector is concentrated in the engineering and scientific services, and computer services industries. These industries, largely Canadian-owned, have access to substantial numbers of scientifically-trained personnel.

The engineering and scientific services industry provides consulting engineering services, surveying, and laboratory, geological, and drafting and design services. It has invested heavily in research and development, with R&D expenditures equal to 5.1 per cent of sales in 1981, indicating a high potential for technological innovation. Although the industry's share of Canadian GDP was only 0.8 per cent in 1981, on an inflation-adjusted basis its output expanded at an average annual rate of 7.0 per cent between 1971 and 1981. Total fee income in 1978 was $1.6 billion, 70.7 per cent of which was generated by services performed by consulting engineers. Ontario accounted for 35.8 per cent of total fee income and 40.1 per cent of consulting income in 1978.

Computer services is another highly innovative industry. Its 1981 R&D-to-sales ratio of 12.3 per cent makes it one of the most R&D-intensive industries. It provides processing services, systems development, software and consulting services as well as sales, rental and maintenance. The industry is concentrated in the Toronto-Ottawa-Montreal area, with Ontario and Quebec accounting for 69.0 per cent and 13.7 per cent, respectively, of the industry's 1981 employment. Increased computer sales have created a tremendous demand for software and services. Employment grew rapidly between 1974 and 1981 in the software and systems side of the industry, resulting in average annual employment growth of 7.5 per cent for the industry as a whole.

High-tech Manufacturing

High-tech industries are defined as those industries with an above-average level of opportunity for technology-based innovation. The lack of direct evidence on innovations means that "technological opportunity" in an industry is usually identified by a high level of R&D relative to industry size[2]. On this basis, eight industries were categorized as high-tech manufacturing[3].

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2 The use of Canadian R&D intensity as a measure of "technological opportunity" tends to exclude those industries that conduct most of their R&D outside the country. Therefore, in this paper, technological opportunity is assessed on the basis of industrial R&D intensity in the United States. See U.S. Department of Commerce, An Assessment of U.S. Competitiveness in High Technology Industries, 1983. Industries identified as being high technology on the basis of their R&D intensity include: aircraft and parts, computers and office equipment, electrical equipment and components, optical and medical instruments, drugs and medicines, plastics and synthetic materials, engines and turbines, agricultural chemicals, professional and scientific instruments and industrial chemicals. With the exception of agricultural chemicals (for which a corresponding Canadian industry could not be identified), the above list was used as the basis for identifying the eight Canadian manufacturing industries described in this paper as exhibiting technological opportunity.

3 While the identification of R&D-intensive industries at the three-digit Standard Industrial Classification (SIC) level is a large improvement over the previously available two-digit SIC level, there are still likely to be some sub-groups of fairly low technology included in the definition, and some high-technology sub-groups excluded. A probable example of the latter is the exclusion of the urban transit equipment industry.

COMPOSITION OF THE HIGH-TECH MANUFACTURING INDUSTRY IN ONTARIO, 1981

Table 3

	Share of Manufacturing Output (per cent)	Employment (number)	Share of Manufacturing Employment (per cent)
<u>More-R&D-Intensive High Tech</u>			
Pharmaceuticals and Medicines	1.3	8,295	0.9
Communications Equipment	2.8	28,059	3.1
Aircraft and Aircraft Parts	1.1	15,800	1.7
Office and Store Machinery	2.2	10,176	1.1
<u>Less-R&D-Intensive High Tech</u>			
Electrical Industrial Equipment	2.2	22,767	2.5
Industrial Chemicals	1.9	15,802	1.7
Plastics and Synthetic Resins	0.8	3,349	0.4
Scientific and Professional Equipment	1.8	18,413	2.0
Total High-Tech Manufacturing	14.2	122,661	13.5

Note: Columns may not sum due to rounding.

Source: Statistics Canada.

Four of the high-tech industries had high ratios of R&D expenditures to value-added in Canada -- pharmaceuticals and medicines, communications equipment manufacturing, aircraft and aircraft parts industries, and office and store machinery manufacturing (predominantly computers, calculators and cash registers). The first three industries each had R&D expenditures that exceeded ten per cent of value-added over the 1976 to 1980 period. While the level of R&D expenditure appears high in the pharmaceuticals industry, much of this spending is attributable to government regulations requiring product testing in Canada[4]. Office and store machinery had expenditures on R&D of between five and ten per cent of value-added.

Four additional industries were included in the high-tech sector on the basis of technological opportunity: electrical industrial equipment, industrial chemicals, plastics and synthetic resins, and scientific and professional equipment. Although these four industries spent less on R&D in Canada

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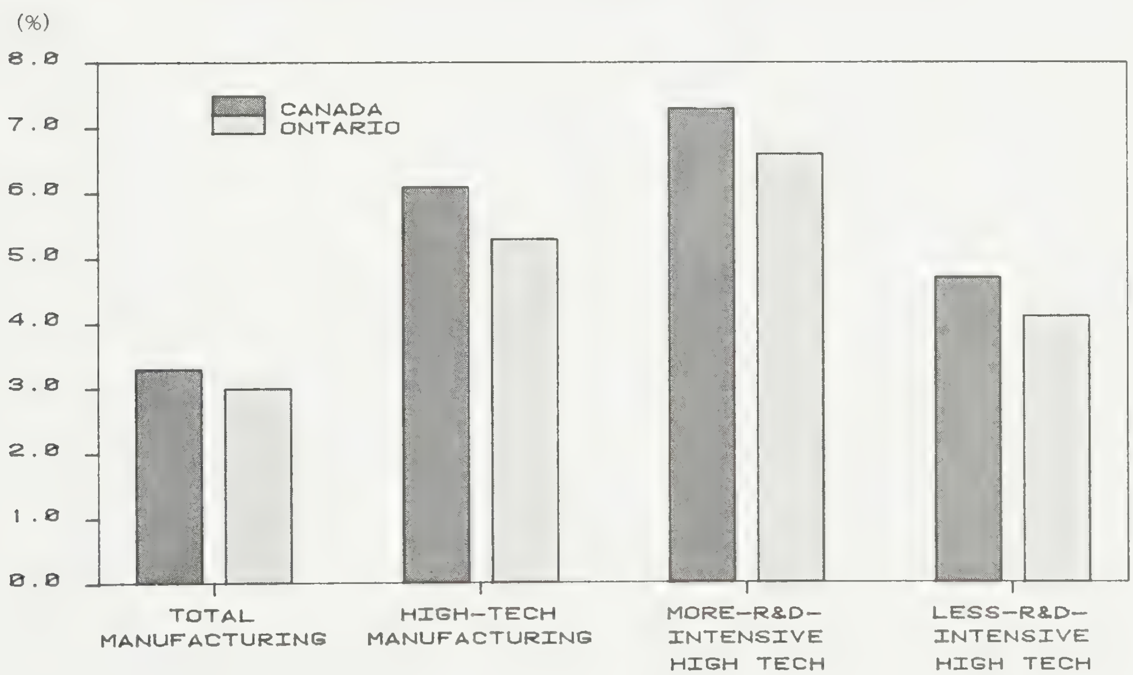
4 The industry has stated that the clinical product testing phase accounts for the largest part of research and development expenditures. Consumer and Corporate Affairs, <u>Compulsory Licensing of Pharmaceuticals</u>, 1983, p. 13.

(between one and one-half and five per cent of value-added) than the first four industries, the output and employment performance of both groups was better than that of total manufacturing. Within high-tech manufacturing, the superior performance of the four more-R&D-intensive industries reflects the rapid growth of demand for their products, and may indicate the importance of conducting research and development in Canada.

Ontario's share of the country's high-tech industries is larger than its share of total manufacturing industries. In 1981, Ontario's share of Canadian high-tech output was 59.0 per cent, compared with its 52.8 per cent share of total manufacturing output. In the high-tech sector, Ontario has a disproportionately large share of the less-R&D-intensive industries, 66.7 per cent in 1981; its share of the more-R&D-intensive industries was 53.4 per cent.

High-tech manufacturing industries provide a significant contribution to overall output growth. Between 1971 and 1981, real output in these industries in both Ontario and Canada grew at an average annual rate nearly double the rate for total manufacturing. In Ontario, high-tech industry growth averaged 5.3 per cent per annum while total manufacturing growth averaged 3.0 per cent.

Average Annual Growth of Real Output in Manufacturing
1971 to 1981



Source: Statistics Canada.

The growth rate of the four more-R&D-intensive industries was significantly higher than that of the less-R&D-intensive industries. Within the high-tech manufacturing sector, office and store machinery was the fastest growing industry, averaging 13.1 per cent annual growth in Ontario between 1971 and 1981. The growth rates of Ontario's aircraft, office and store machinery, and industrial chemicals industries lagged well behind the Canadian growth rates, but the rate of growth of Ontario's plastics industry surpassed that of Canada's.

The high-tech manufacturing sector in Ontario is growing rapidly because it has been able to take advantage of expanding world markets. The widening trade deficit in high-tech industries is often cited as evidence of Canada's declining competitiveness in this area. However, in these industries the volume of trade increased and prices rose during the 1970s. When these factors are taken into account, Canada's competitiveness actually improved between 1971 and 1982 in all high-tech industries except office and store machinery[5].

During the 1970s, the high-tech industries outpaced total manufacturing in employment growth. Employment in high-tech manufacturing increased by an average 2.3 per cent per annum in Ontario (2.4 per cent in Canada) compared with 1.3 per cent average annual growth in total manufacturing. Indeed, in recent years, employment growth in the high-tech industries in Ontario has been particularly strong. Between 1979 and 1981 (the latest year available), there was an 11.7 per cent increase in employment in the high-tech industries (18.4 per cent in R&D-intensive high-tech) and a 0.2 per cent decline in total manufacturing employment.

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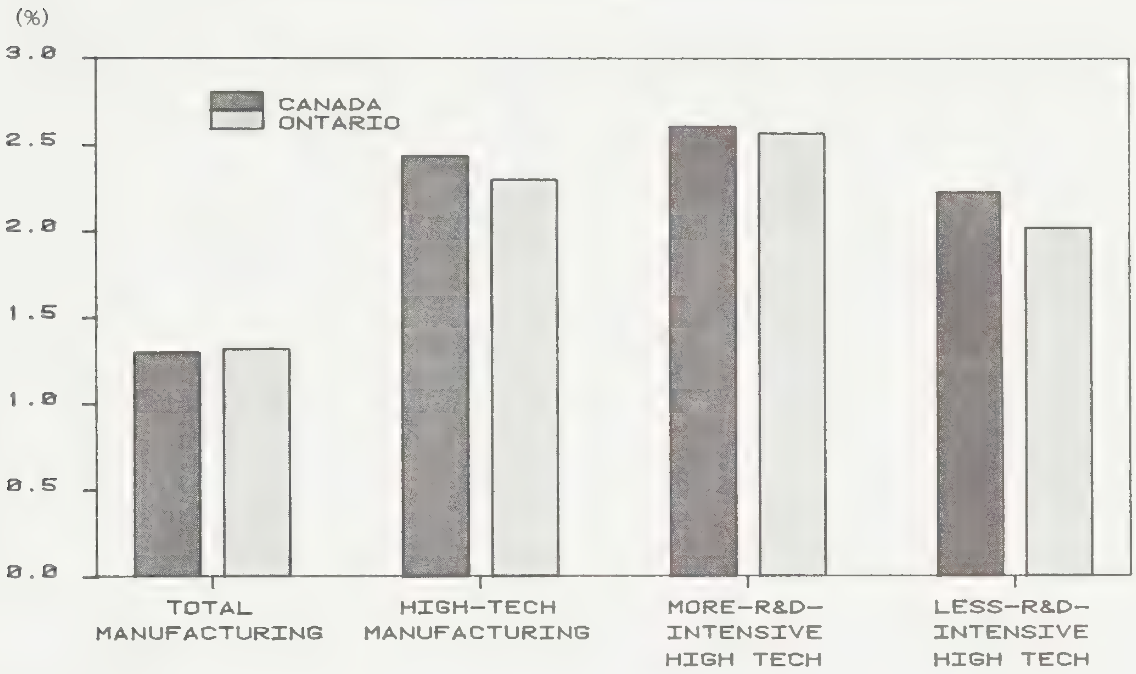
5 A widening trade deficit in the high-tech industries should be normalized (by taking the trade balance as a proportion of total trade) to indicate changes in competitiveness over time. For Canada, the normalized trade balance improved from 1971 to 1982 for all the high-tech industries except office and store machinery.

Average Annual Growth of Employment in Manufacturing 1971 to 1981



Source: Statistics Canada.

In 1981, high-tech manufacturing employed 13.5 per cent of the manufacturing labour force in Ontario, up from 12.2 per cent in 1971. The relative size of the high-tech sector should not be exaggerated, particularly given the broad definition of high-tech noted above, but its rapid growth is producing shifts in the structure of the manufacturing sector in Ontario and in opportunities for employment. Between 1971 and 1981, the high-tech sector in Ontario created more than its share of new manufacturing jobs -- 22.3 per cent of the total.

The high-tech manufacturing sector and its support industries are expected to continue to grow rapidly over the next 20 years, but the relatively small size of the sector means that the majority of new jobs in the Ontario economy will be in other industries. High-technology employment, however, can have a large impact on a local economy, as seen in California (Silicon Valley), Massachusetts and New Hampshire (Route 128), and the Ottawa region. In a relatively short period, these areas have developed substantial industrial bases built on high-technology industries.

III THE ROLE OF DIFFUSION IN ECONOMIC TRANSFORMATION

Diffusion refers to the adoption of a new process or imitation of a new product by industry after it has been successfully commercialized. While the overall process of technological change takes place in three phases -- invention, innovation and diffusion -- these usually overlap and influence each other. For example, after new products and processes have started to diffuse throughout the economy, R&D is performed to modify and improve them.

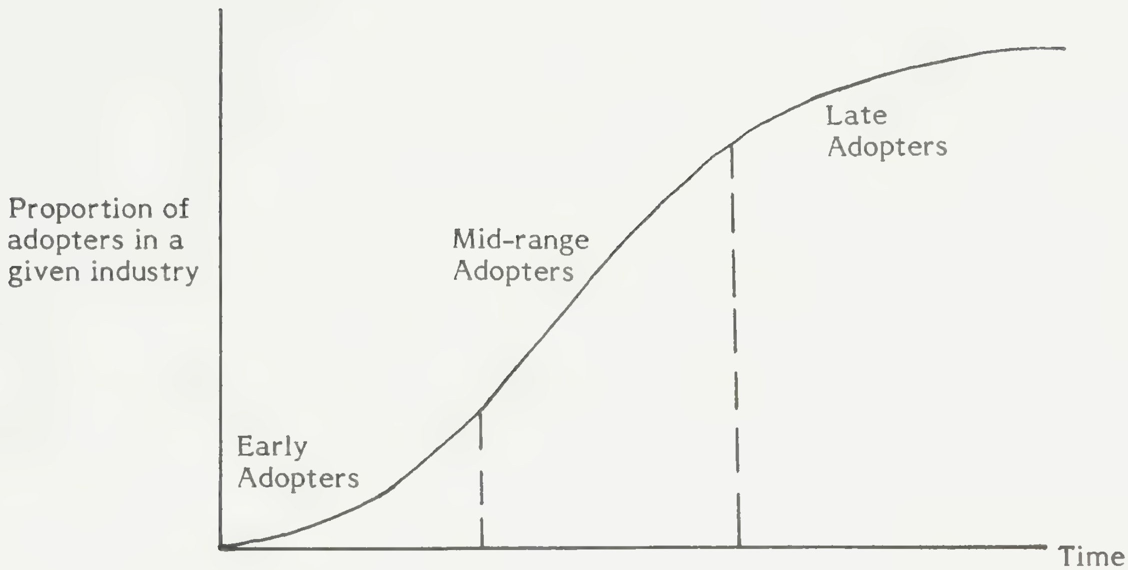
As innovations diffuse throughout the economy, they help to enhance product quality, reduce costs and improve productivity. Frequently, non-manufacturing sectors benefit from these innovations. Because substantial economic benefits can be gained through the adoption of new technology, the apparently slow diffusion of technology in Canada is of some concern. This section discusses the importance of early adoption of technology and compares Canada's rate of technology adoption to those of other advanced countries.

The Importance of Early Adoption

The diffusion of both product and process innovations is significant for the broad range of industries in Ontario. Some established manufacturing industries are already undergoing transformation with the application of new technologies. For example, the use of computer-aided design and manufacturing technology is becoming more widespread, particularly in the machine tool industry, the automobile and aerospace industries and the resource sector. It also has important implications for more traditional industries such as footwear. In the service sector, as well, the adoption of new technology can improve productivity.

Relatively few firms are able or willing to accept the high levels of risk associated with the early stages of diffusion. This typically results in an S-shaped diffusion curve over time. As the level of uncertainty decreases, more firms adopt the innovation until saturation is reached.

Diffusion Path of Innovations



Source: Economic Council of Canada, The Bottom Line: Technology, Trade, and Income Growth, 1983.

If more Canadian firms were early or mid-range adopters, consumers would benefit earlier from lower prices and better product quality. At the same time, early adopting firms, particularly if they were able to improve upon an innovation, would have fewer competitors, earn higher profits and be in a more favourable export position. Fast diffusion of process innovations also gives industry a lead in maintaining productivity and international competitiveness. This, in turn, permits higher incomes and improved living standards.

Individual firms decide whether to adopt an innovation on the basis of an assessment of its potential profitability. The benefits (lower production costs or improved product quality leading to increased sales) are weighed against the costs (capital expenses, costs associated with assessing and adapting the innovation, and the amount of risk involved). While this type of assessment is essential to any investment decision, the risk involved in the early adoption of new technology is greater than average. Therefore, firms adopting innovations require the potential returns to be greater than average.

These firm-level decisions are influenced by structural factors, such as the size of the firm, the degree of competition in the adopting industry and domestic or foreign ownership of the firm. Firms also consider the availability of labour skilled in the use of new technologies. The availability of information about innovations and the cost of obtaining this information play an important role in influencing technology-adoption patterns.

The readiness of labour to work with new technology may also affect the rate of diffusion. While the level of education and training in the work-force is important, so is the industrial relations environment. The introduction of more productive technology is bound to have an effect on the skill requirements and employment levels in a firm or industry. Helping workers to adjust to these changes through retraining requires the cooperation of management, labour and government. It is important that all affected individuals should see the benefits of adopting new technologies, and that these benefits should be shared by everyone.

Diffusion in an International Context

Many of the new products imitated and processes used by Canadian industries were not originally developed in Canada. Indeed, according to the National Research Council, Canada's output of technology amounts to less than one per cent of the total world output[6]. Foreign applications for patents in Canada dwarf those of Canadians, as seen in Table 4. This is not unusual, given the international nature of the technology pool.

Canada benefits from the research and development conducted in foreign countries by importing technology. Like most countries other than the United States, Japan and Germany, Canada is a net importer of technology. These imported technologies can be the basis for a rejuvenated Canadian industry catering to both domestic and foreign markets.

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6 National Research Council, The Urgent Investment: A Long Range Plan for the National Research Council of Canada, 1980, p. 68.

APPLICANTS FOR CANADIAN PATENTS BY COUNTRY OF ORIGIN
(per cent of total patents) Table 4

	1971-1975	1976-1980
Canada	6.7	7.2
United States	56.8	54.7
Germany	7.5	7.8
Japan	6.5	7.2
United Kingdom	6.1	5.2
France	3.9	4.4

Source: Statistics Canada, Canadian Science Indicators, 1983.

Diffusion in Canada

The diffusion of new technology to existing industries is normally an extremely slow process. It can take more than 20 years after initial commercialization before a new product or process is commonly adopted. Long adoption lags are not unusual, but the diffusion process generally proceeds at a slower rate in Canada than in the United States and Western Europe.

A recent Economic Council of Canada study[7] on innovations in five industries shows that the average lag for the first adoption of new processes, most of which were developed abroad, by firms in Canada was nine years. For new products the average lag was seven years. For example, a technique for the continuous processing of polystyrene was first adopted by a Canadian firm seven years after it was developed in Italy. Blast furnace oxygen enrichment, widely used throughout Europe, the United States and Japan, was first adopted in Canada 22 years after it was developed abroad. New products, such as various bonding agents, thickeners or resins, were imitated or improved upon by the plastics compounds and synthetic resins industry in Canada several years after their initial development abroad. According to the same study, the average time required to imitate a significant innovation developed outside Canada varied between industries -- from 5.5 years in telecommunications equipment to 11.5 years in smelting and refining.

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7 D.P. De Melto, et al., Preliminary Report: Innovation and Technological Change in Five Canadian Industries, Economic Council of Canada, 1980.

AVERAGE LAG IN THE ENTRY OF NEW INNOVATIONS INTO CANADA, BY INDUSTRY

Table 5

Industry	Years
Telecommunications Equipment and Components	5.5
Plastics Compounds and Synthetic Resins	7.4
Electrical Industrial Equipment	9.1
Crude Petroleum Production	10.9
Smelting and Refining	11.5
Average	8.0

Note: Product and process innovations developed abroad.

Source: D.P. De Melto, et al., Preliminary Report: Innovation and Technological Change in Five Canadian Industries, Economic Council of Canada, 1980.

While long diffusion lags are common in all countries, Canada's international competitiveness depends, in part, on its rate of adoption of significant innovations relative to those of other countries. The evidence on this is fragmentary, but one inter-country comparison[8] examined the diffusion of special presses in the pulp and paper industry, tufting machinery in the textile industry and numerical control in the tool and die industry. In all three cases, the rate of diffusion, as measured by the proportion of firms that adopted the innovation within a given period, was slower in Canada than in the United States and Europe.

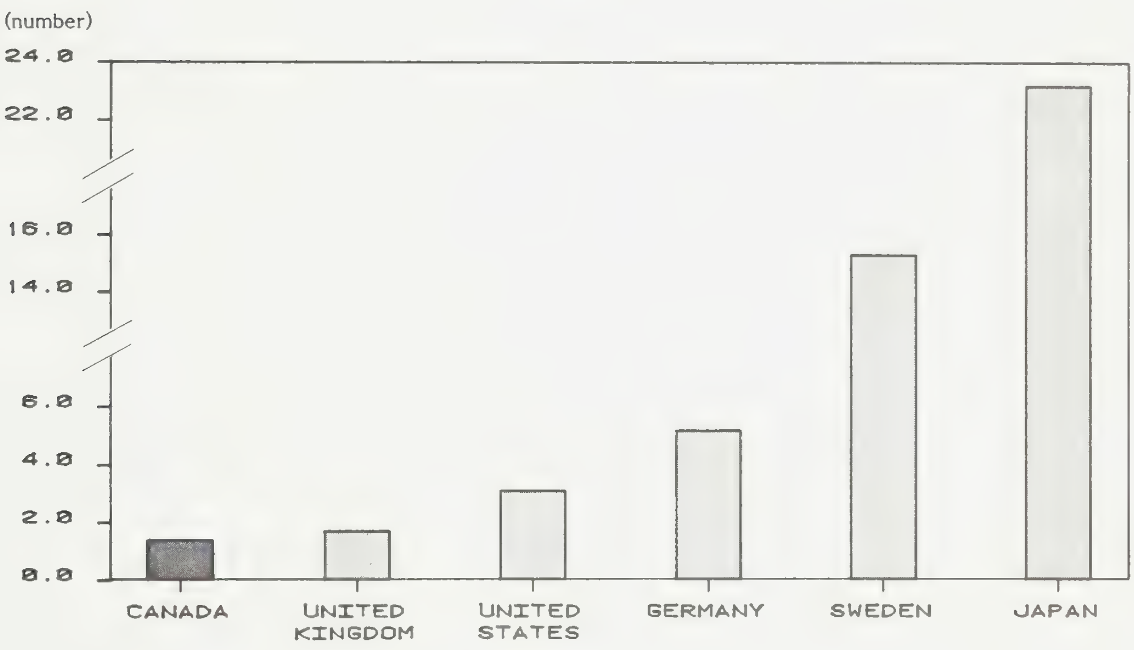
Recent evidence on the adoption of electronic data processing by service industries in Canada is somewhat more ambiguous but suggests a similar pattern[9]. Hospitals and department stores adopted this technology earlier in the United States than in Canada. On the other hand, Canadian university libraries became automated earlier than their American counterparts.

8 Steven Globerman, Technological Diffusion in Canadian Manufacturing Industries, ITC, Technological Innovation Studies Program Research Report 17, 1974.

9 Steven Globerman, The Adoption of Computer Technology in Selected Canadian Service Industries, 1981, p. 41.

The number of robots per 10,000 employees in manufacturing is an indicator of the diffusion of this technology[10]. In 1982, Japan led with 23.2, followed by Sweden with 15.3 and Germany with 5.2. In the same year, Canada had only 1.4 robots in use for every 10,000 employees in manufacturing, less than one-half the American level of 3.1. There are many reasons for the different levels of robot use in the various countries: different industrial structures, labour costs, labour shortages, levels of awareness or domestic production capabilities. For example, it has been suggested that a shortage of engineers and technicians experienced in robot applications inhibits the diffusion of robots in Canada[11]. The evidence of Canada's relatively slow rate of technology adoption is disturbing because robotics is considered to be well-suited to the short production runs that characterize much of Canadian manufacturing.

Robots per 10,000 Employees in Manufacturing
1982



Sources: Robot Institute of America; U.S. Department of Labor.

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10 Robot Institute of America, quoted in Japan 1983, An International Comparison, Kerzai Koho Centre, September 1983. 1982 employment data from the Bureau of Labour Statistics, U.S. Department of Labor.

11 OECD, The Impact of Industrial Robots on the Manufacturing Industries of Member Countries, 1983, p. 44.

There is also a regional dimension to diffusion rates in Canada. For example, research done for the Economic Council of Canada suggests that computers were adopted first in Ontario. Other regions followed with approximate average lags of one and one-quarter years for Quebec, two years for the Prairie region, three years for British Columbia and three and one-half years for the Atlantic region[12]. These interregional lags may be due to factors such as population concentration and distance from technology suppliers, but it is also likely that they are linked to differences in regional economic structures, including differences in industrial specialization or firm size.

Excessive lags in Canada's rate of technology adoption mean that productivity gains are not captured quickly by existing industries, adversely affecting their international competitiveness. However, the capacity to absorb technology is always limited. It would not make economic sense for firms to discard equipment that, while outdated, contributes more to profit than would new investment.

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12 F. Martin, et al., <u>The Interregional Diffusion of Innovations in Canada</u>, Economic Council of Canada, 1979, p. 42.

IV DETERMINANTS OF INNOVATION AND DIFFUSION

There are many economic and social factors that affect technological innovation and the rate of diffusion. Some of these can be influenced by government policy, although promoting technological advance may not be the primary policy objective. These factors include:

- the economic environment;
- structural factors such as market size, firm size, the level of foreign ownership and the degree of competition;
- availability of skilled personnel;
- the level of R&D funding; and
- the supply and cost of financial capital.

Government policies that directly assist innovation and diffusion in an industry or firm can also have a significant impact, but only if they take place in an environment conducive to technological development. A review of government programs designed to facilitate the growth of high-tech industries and the adoption of new technology is included in Appendix B.

The Economic Environment

Innovative activity, as well as the adoption of new technologies, is directly affected by the general economic climate and thus by government macroeconomic policies. Steady growth, controlled inflation and low real interest rates create an environment conducive to innovation and rapid diffusion.

In contrast, when sales and profits are depressed there is greater commercial risk in introducing innovations. Depressed demand also results in capacity underutilization, so that firms are less likely to adopt new technology. High real interest rates effectively raise the cost to firms of introducing new technology, and thus slow the rate of technological diffusion. When demand is too high, producing inflationary growth, financial resources may be diverted from research and innovation to expand production.

Structural Factors

A country's record of innovation and its rate of technology adoption are greatly influenced by structural factors such as the size of the market, the level of competition, the size of firms and the degree of foreign ownership.

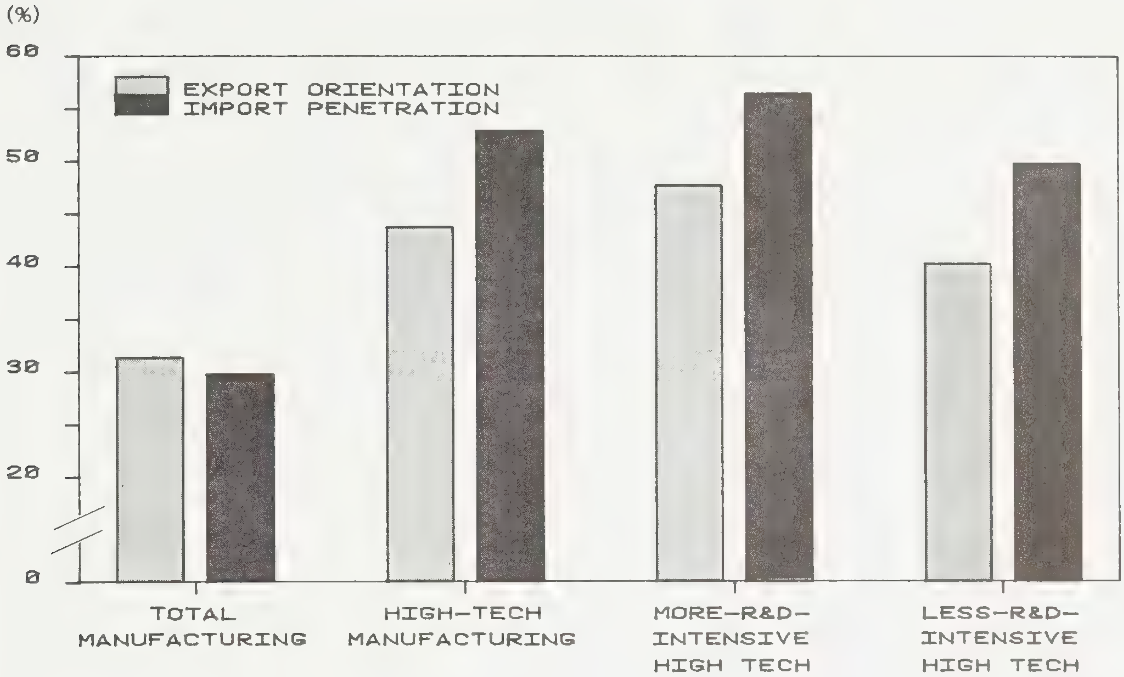
Market Size and Competition

Small market size has frequently been cited as a reason for the lack of Canadian innovation. Firms that innovate in the United States sell to a domestic market that is ten times as large as Canada's; Japanese firms have the advantage of a home market four times as large as Canada's; the European Economic Community has opened a market for its member countries that is eight times as large as Canada's.

Trade policies that pursue export access can expand effective market size. Increased access to large foreign markets allows firms to spread the fixed costs of R&D and innovation over a greater sales volume. Specialization in production for larger markets increases the length of production runs and improves the incentive for a firm to adopt new technology.

The benefits of both domestic innovation and early adoption of foreign technology can be gained if Canada exports a few technologies to the large world market and acts as a small market for a broad range of foreign technologies. The extent to which the high-tech industries, in particular, have taken advantage of larger markets by exporting is shown in the following figure.

Export Orientation and Import Penetration in Canadian Manufacturing 1982



Note: Export orientation is the ratio of the value of goods exported to the total value of shipments made by firms in Canada. Import penetration is the ratio of the value of goods imported to the total value of purchases made in the Canadian market.

Source: Industry, Trade and Commerce, Manufacturing Trade and Measures, 1966-1982.

It has been established that competitive pressure speeds technological diffusion. Competitive pressure can result from vigorous domestic rivalry, entry of new firms into an industry or competition from imports. The spur to the adoption of advanced technology provided by import competition, while painful at times, is an important benefit of trade.

Firm Size

Firms of all sizes contribute to the innovation and diffusion processes. The greatest relative success of small firms is in invention and early commercialization, whereas the relative strengths of larger firms lie in widespread marketing and distribution, large-scale production, innovation

requiring substantial capital resources and the faster adoption of process technology.

Small corporations play a dynamic role in many emerging industries. New small firms are motivated to innovate. When small firms spin off from large firms or university research programs, they often develop inventions or ideas and turn them into innovations. Moreover, the inventor-entrepreneur often creates novel concepts that are subsequently perfected and commercialized by large firms. While most small firms do not innovate, those that do have the advantages of flexibility, low costs and rapid internal communication.

The contribution of small firms to innovation varies among industries. In general, those industries where small firms make a significant contribution to innovation have low capital intensity or low product development costs. These include: the electronics industry, the scientific and professional instruments industry and the textiles, leather and furniture industries. Large firms dominate in innovation where the investment required to innovate is large; they also dominate where the minimum size of firm that could efficiently use the resulting product or process is relatively large. Examples of industries where large firms dominate in innovation include: aerospace, pharmaceuticals, steel, aluminum, and synthetic resins.

Large firms generally adopt new technology faster than small firms because of their greater financial resources; their greater ability to monitor, assess and adapt technical developments; and their greater likelihood of needing to replace some equipment at any given time. However, small firms completely replace old technologies more quickly once an innovation has been adopted, partly because of the smaller absolute amounts of capital involved. Small firms may also be quicker to adopt innovations that allow efficient production on a smaller scale.

As can be seen from Table 6, Canada had 19 of the 500 largest industrial corporations in the world in 1979. This is a respectable proportion, given Canada's relative size. However, the Canadian firms are concentrated in the smaller size brackets. More significantly, only two of them would be considered high-tech, compared to over 60 in the United States. The two,

Northern Telecom and Canada Development Corporation[13], both had sales in 1979 between $1 billion and $2 billion (U.S.). The relative lack of larger-scale firms in Canada represents a structural impediment to both the widespread commercialization and distribution of Canadian innovations, and the rapid diffusion of technology.

THE WORLD'S 500 LARGEST INDUSTRIAL CORPORATIONS, BY SALES AND COUNTRY OF ORIGIN, 1979 — Table 6

	Number of corporations with sales of ($U.S. billions)					
Country	Over 10	5-10	3-5	2-3	1-2	Total
United States	20	38	53	62	46	219
Japan	6	5	12	21	27	71
United Kingdom	2	8	10	15	16	51
Germany	7	9	8	8	5	37
France	4	7	5	5	6	27
Canada	-	4	1	7	7	19
Others	8	10	17	19	22	76

Source: John Hein, The World's Multinationals: A Global Challenge, The Conference Board, Information Bulletin #84.

Foreign Ownership

An issue of particular relevance to Canada is the effect of foreign ownership on the rate of technological change. While foreign-owned firms in Canada may be more technology-intensive than their Canadian counterparts, they are less research-intensive and less innovative because they tend to rely on the know-how developed by their parents and affiliates. It is often more efficient for the multinational to centralize R&D at the head office. But the reduced R&D and innovative capability in Canada means that external benefits from R&D and opportunities for knowledge-intensive employment may be lost.

13 Canada Development Corporation is a publicly and privately-owned conglomerate with interests in petrochemicals, mining, oil and gas, medical research, electronics and venture capital companies.

Furthermore, the degree of foreign ownership in Canadian manufacturing has reduced the demands for technological innovation that are placed on Canadian suppliers. For example, a large foreign subsidiary may subcontract items for production in its home country rather than in Canada, thus denying the opportunity for development of a domestic capability. This is particularly apparent in cases of joint development programs between the parent's innovation centre and local suppliers in the home country.

By international standards, the levels of foreign ownership in high-tech manufacturing industries in Canada are exceptionally high[14]. In 1980, the levels of foreign ownership in the pharmaceuticals, office and store machinery, electrical industrial equipment, and plastics and synthetic resins industries exceeded 80 per cent, compared to 45 per cent for total manufacturing.

International product mandating offers a means of overcoming some of the impediments to R&D, innovation and exports arising from foreign ownership. An Ontario Ministry of Industry and Trade examination of foreign subsidiaries in manufacturing found that 20 per cent had international product mandates and nine per cent had North American mandates. Another eight per cent were occasional exporters, but the remaining 63 per cent produced for the Canadian market alone. These estimates provide some evidence of international product mandating. However, many foreign-based multinationals may be reluctant to assign such mandates to subsidiaries because of economies of scale in research and cost efficiencies in centralized corporate control.

While foreign-owned firms tend to perform less R&D in Canada, and are less likely to innovate, they can speed the diffusion of new foreign technologies to Canada through intracorporate transfers. An Economic Council of Canada analysis recently showed that technology transfers through multinationals occur faster and are implemented more efficiently than at-arm's-length transfers under licensing arrangements[15].

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14 K.S. Palda and B. Pazderka, Approaches to an International Comparison of Canada's R&D Expenditures, Economic Council of Canada, 1982, p. 52.

15 Economic Council of Canada, The Bottom Line: Technology, Trade, and Income Growth, 1983, p. 54.

Foreign ownership, however, may also inhibit the diffusion of technology because foreign-owned firms tend to have fewer linkages with Canadian supplier firms. The significance of this has been noted in a background study prepared for the Science Council of Canada[16]. As a result of their tendency to source outside Canada, foreign subsidiaries place fewer demands on Canadian suppliers for products requiring up-to-date technological capabilities. Therefore, they have less incentive to assist in developing the expertise of Canadian suppliers. This effect could explain, in part, why the rate of technological diffusion remains slower in Canada than in other advanced industrialized countries, despite Canada's much higher level of foreign ownership in manufacturing.

Human Resources

The availability of well-trained technical, scientific and managerial personnel has long been recognized as a major contributor to technological innovation. Qualified researchers with graduate-level training in the natural or applied sciences are essential for the performance of R&D. Innovative firms require personnel capable of using technically-advanced equipment and of adjusting to frequent changes in products and processes, in addition to management skilled in the many facets of product development and marketing.

Universities and community colleges train engineers, business graduates, technologists and other personnel essential for innovation and diffusion. Universities also play a crucial role in maintaining basic expertise in fields that could become important in the future. The importance of the university environment -- both in educating scientists and engineers and in conducting research -- is illustrated by the growth of centres of innovation around important educational institutions in the Boston and Silicon Valley areas of the United States. This growth also reflects the fact that high-tech firms have judged the availability of skilled labour to be the most important criterion in choosing an investment location.

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16 J. Britton and J. Gilmour, The Weakest Link: A Technological Perspective on Canadian Industrial Underdevelopment, Science Council of Canada, Background Study No. 43, 1978, p. 143-144.

Enrolments in post-secondary institutions as a percentage of the 20 to 24 year-old age group in Ontario and Canada compare favourably with those of other countries, with the exception of the United States, as seen in Table 7. Canada had a rapid increase in post-secondary enrolment rates throughout the 1960s, although this slowed significantly in the 1970s. There was a substantial shift in undergraduate enrolment from education, humanities and most social sciences to business, engineering and applied sciences during the 1970s.

POST-SECONDARY ENROLMENT RATES IN ONTARIO AND SELECTED COUNTRIES, 1965 and 1980
(per cent)

Table 7

	1965	1980
Ontario	22.7	41.4
Canada	25.1	38.5
U.S.A.	40.2	57.1
Sweden	13.1	36.9
Japan	12.9	30.2
Germany	8.8	27.6
France	18.2	25.5
United Kingdom	11.8	20.1

Note: Total post-secondary enrolment as a per cent of 20 to 24 year-old population.

Sources: UNESCO; Statistics Canada.

The much higher post-secondary enrolment rate in the United States is consistent with its pre-eminent role in innovation. The gap between Canada and the United States may have to be narrowed if the Canadian economy is to increase its relative technological sophistication. Given the importance of graduate education in science and engineering for research and innovation, it is significant that the absolute number of doctoral degrees in these disciplines awarded to Canadian residents has been declining since 1973.

Many studies have emphasized the crucial role of management in the adoption-decision process. Canadian managers have tended to be older and less educated than their counterparts in the United States, and this has been suggested as a reason for the poor rates of technology diffusion in Canada.

Technology can be embodied in people as well as in capital. Where the interfirm mobility of scientific, technical and certain managerial personnel is high, substantial technological transfers can result. However, the mobility of labour can also reduce the incentive for firms to invest in training. Conversely, the "life-time employment" tradition of large Japanese firms is a significant incentive for their in-house training programs.

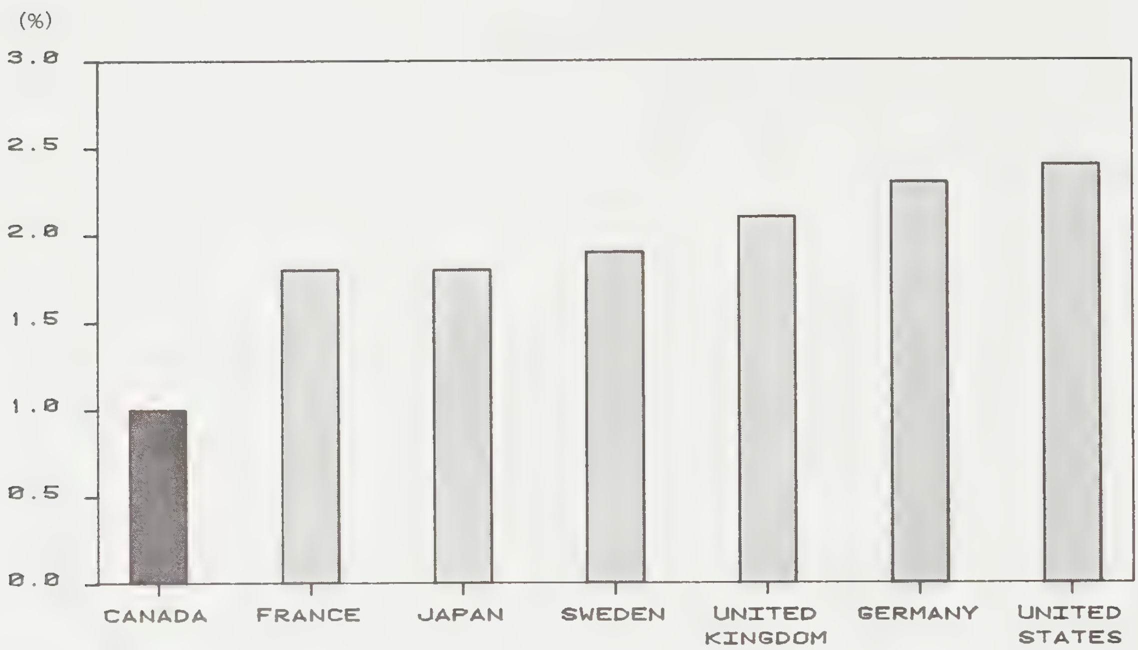
Research and Development

Domestic research and development provides the basis for many new product and process innovations in Canada. Because exposure to the marketplace enhances the prospects for commercializing innovations, the potential economic benefits from R&D are greatest when research is undertaken by industry. A survey of 283 major innovations in five Canadian industries found that the technology for two-thirds of the innovations was primarily developed in-house by the innovating firm. A further seven per cent utilized both internally-developed and externally-acquired technologies.

The existence of in-house R&D also enables a firm to monitor, assess, adopt or improve the innovations of other firms or research institutions. The vast majority of the approximately 32,000 small manufacturing companies in Canada do not perform R&D, and thus do not have the advantages of large firms which use their research and development facilities to search the world for applicable technologies. Most small Canadian firms acquire information about external technologies through capital goods and materials suppliers, research institutions, customers, consultants and industry associations. Other sources of information, such as patent descriptions, are not widely used.

In 1979, Canada's R&D performance fell short of those of other industrialized countries. Preliminary estimates for 1983 indicate that the ratio of R&D to GNP in Canada has risen to 1.3 per cent, still well below those of Canada's international competitors.

Ratio of Natural Sciences and Engineering R&D to Output
1979



Note: United States and France include R&D expenditures on social sciences and humanities.

Source: OECD, International Survey of the Resources Devoted to R&D by OECD Member Countries, 1982.

The constraints on Canadian research and development performance frequently mirror the constraints on innovation -- small market size, a relatively small number of large firms and a high level of foreign ownership.

Venture Capital

A major determinant of the successful commercialization of a product or process innovation is the availability of venture capital after the research and development stage. A Statistics Canada survey showed that R&D expenses were generally the most costly single component of technological innovation[17]. R&D expenses, at the median, were 37 per cent of the total cost. Significant

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17 H. Stead, "The Costs of Technological Innovation", in Research Policy, 1976, p. 7.

financial capital is required at the design, engineering and tooling stages, as well as for marketing start-up. But investing in innovation is risky. A typical estimate[18] is that five out of every ten products that emerge from R&D fail in product and market tests. Only two become true commercial successes. An even riskier stage in the innovation process -- one identified as being under-financed in Canada -- is the final pre-venture capital, or prototype development, stage. Small firms, which generally must seek outside financing, have the most difficulty in obtaining pre-venture and venture capital. Young firms frequently need management and technical expertise as well as capital.

Private sector venture capital investment is a growing but volatile business in Canada, as seen in Table 8. The private sector members of the Association of Canadian Venture Capital Companies (ACVCC) invested $21.6 million in 36 deals in Ontario in 1982. Only a portion of the total ACVCC portfolio was invested in high-technology products -- 35 per cent of total investments in 1982.

CANADIAN VENTURE CAPITAL INVESTMENTS, 1976 to 1982 — Table 8

Location of Principal Facility of Recipient	1982		1981		1976-1980 Average	
	number	$ millions	number	$ millions	number	$ millions
Ontario	36	21.6	60	46.9	20	8.7
Canada	88	61.7	113	85.5	45	23.8
Foreign Countries	35	17.2	65	35.4	8	4.2
Total[1]	123	78.9	180	121.2	56	28.6

1. Includes investments with location unspecified.

Source: The Association of Canadian Venture Capital Companies, Unaudited Information Regarding the Investment Activities of the Association Members, 1983.

Recently, there have been signs of an increasing supply of financial capital being made available to innovative firms. Changes in the Toronto Stock Exchange listing requirements have enabled many small, privately-owned, high-tech companies to gain access to significant amounts of expansion capital

18 U.S. Department of Commerce, An Assessment of U.S. Competitiveness in High Technology Industries, 1983, p. 68.

through public share offers. These firms have usually graduated beyond the venture capital financing stage.

The return demanded by the capital markets for investing in small-firm ventures will include a premium to compensate for the higher risk involved. There is a bias against the allocation of capital to small technology-based firms because their most important resources are often ideas, which are not generally acceptable as collateral.

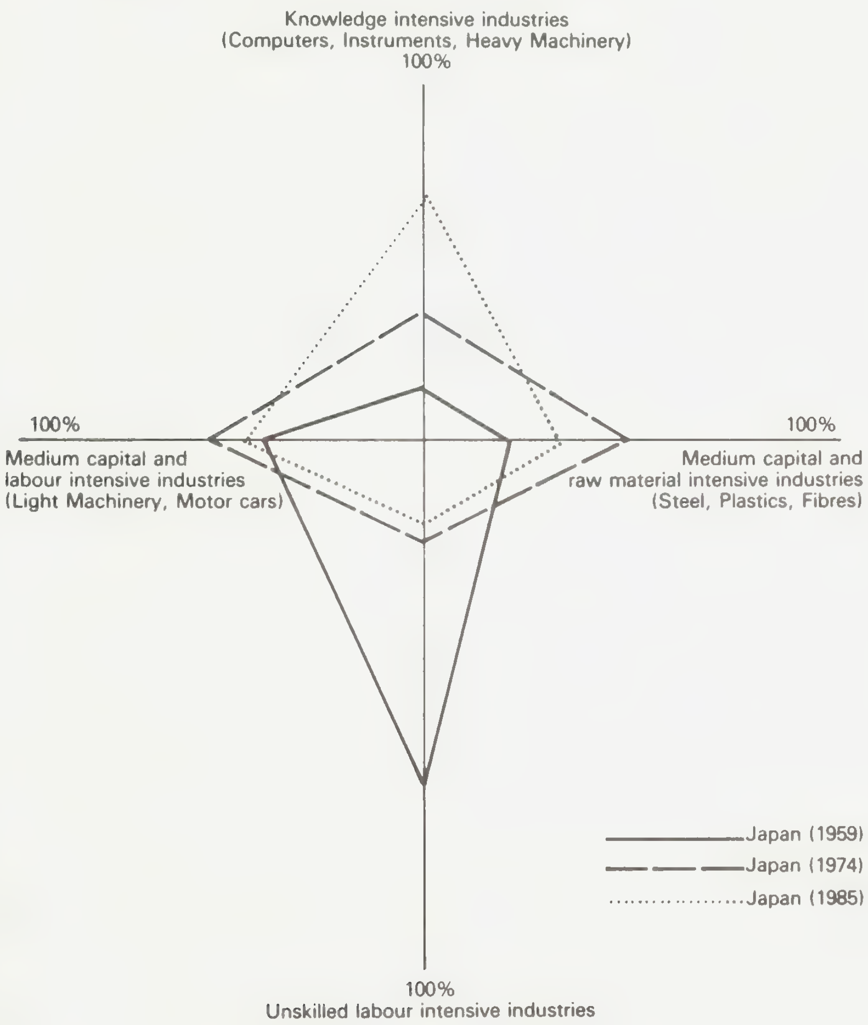
The corporate tax system tends to favour larger firms in the undertaking of risky new ventures. Large firms with taxable income can deduct the losses arising from unsuccessful ventures for tax purposes. To the extent that small firms do not have taxable income, they lack this opportunity.

Canadian public policies with respect to the regulation of financial institutions have encouraged conservative lending practices. This may have placed innovative small firms and other risky clients at a disadvantage with respect to their counterparts in other countries.

V POLICIES FOR ECONOMIC TRANSFORMATION

Japan is commonly cited as a country where government, through deliberate policy actions, contributed to a shift from labour-intensive, to capital-intensive, to knowledge-intensive manufacturing. The evolution of the economy of Japan, as seen by its government, is illustrated in the following figure.

The Evolution of Japan's Industrial Structure



Source: Japanese Economic Planning Agency, Japan Economic Survey (1974-75). See Ira C. Magaziner and Thomas M. Hout, Japanese Industrial Policy, 1980, p. 7.

Continued integration of the less-developed countries into the world economy, and intensified competition from developed countries, will lead Canada to rely more heavily on innovation and the use of state-of-the-art technology. The restructuring of the economy will occur primarily through the initiatives of individuals and private firms responding to market forces, especially international competition. Government policies, however, can facilitate transformation by supporting innovation and encouraging established industries to adopt up-to-date technology.

This section of the paper examines a number of government policies that can influence the realization of technological potential. It also discusses options for policy that could strengthen technological innovation and diffusion.

The Contribution of Government

During this period of economic transformation, both the federal and provincial governments can adopt policies to help accelerate the shift toward knowledge-intensive activities.

In general, individuals and firms are better placed than government to decide which investments in human or physical capital offer the best prospects. Sometimes, however, firms are reluctant to invest because they are unable to capture in profits all the benefits they create for society. For example, firms may be unwilling to train employees who could be hired away by competitors. These investments may only occur with government support.

Although other policy objectives, sometimes conflicting ones, must be taken into account, governments can promote technical advance with policies that relate to:

- the economic environment;
- international trade, competition and foreign investment;
- capital markets;
- human resources;
- R&D funding; and
- industrial assistance for innovation and diffusion.

Stabilization, international trade, competition and foreign ownership policies are largely federal responsibilities. Ontario's position on these is consistent with the promotion of technical advance and is well-documented elsewhere.

In recent years, Ontario has introduced significant measures to overcome apparent deficiencies in the supply of capital to innovative firms. These include the establishment of IDEA Corporation and the provision of tax incentives through Small Business Development Corporations. Further details are provided in Appendix B.

Future Policy Directions

In the context of the transformation of the Ontario economy, four policy areas are emerging as priorities: human resources, research and development, and industry policies to encourage both innovation and diffusion. Ontario already has in place a number of programs in these areas. These are listed in Appendix B. The continuing challenge is to adapt Ontario's policies to changing circumstances.

Human Resources Policy

Government support of education and training can, to some extent, be used as an economic development policy to encourage knowledge-intensive activities. This is particularly the case where training and education encourage complementary investments by private firms in industries dependent on the availability of a well-trained and educated work-force. In part because many firms are reluctant to finance the training of workers who could be hired away by their competitors, governments have become involved in education and training.

The Minister of Colleges and Universities recently established a commission to consider, among other matters, the advisability of developing specialized roles for some universities and of reducing program duplication. In announcing the Bovey Commission, the Honourable Bette Stephenson stated that the establishment of specialized institutes, through cooperative involvement of

the universities and the business sector, could contribute to economic recovery. Such institutes could also provide international calibre research and graduate programs, and contribute significant impetus to technological innovation and diffusion. This might encourage complementary investments by private firms.

Skilled, knowledgeable and experienced individuals contribute to innovation and the adoption of new technology by a firm. While education and training in schools, colleges and universities are essential, it has become apparent that company-provided education and training are characteristic of well-managed firms in Japan and other advanced countries. Up-to-date, innovative and R&D-performing firms are better positioned to identify their future skill requirements and initiate training programs. Thus, the various policies recommended to increase innovation and diffusion could also stimulate industrial training.

Ontario has a wide range of training programs. The Training in Business and Industry programs and the Ontario Training Incentive Program are recent initiatives designed to support firms that train their employees. Another approach which could be considered would involve supporting a limited number of technologically-advanced firms as "training leaders". These firms would be encouraged to establish training programs and would be supported for training in excess of their own requirements. By allowing these firms to specialize in training, many would achieve economies of scale -- permitting them to conduct their own training more efficiently. The training leader would probably be a major company in an industry. Such a program would seek to encourage industry suppliers and competitors to adopt the approaches and techniques of the training leader as industry standards.

The readiness of individuals to learn new skills and work with new technologies, and the incentive for firms to invest in human capital are, in part, functions of the industrial relations climate. Increasingly, North American labour and management are realizing their common interest in cooperative training and employee adjustment programs. For example, the United Auto Workers and the Ford Motor Company have jointly established an employee development and training program.

Providing economic security to employees affected by technological change -- without introducing self-defeating impediments to the adoption of new techniques and practices -- is a problem that will be solved most effectively if the solution is arrived at voluntarily by firms and their employees. Government programs could assist this process by encouraging labour-management cooperation in industrial training and adjustment programs. The newly formed Canadian Labour Market and Productivity Centre may be able to provide some much needed assistance in this area.

R&D Policy

Companies in Ontario benefit from generous corporate tax treatment of their R&D expenditures[19]. However, there may be room to improve the efficiency of R&D tax expenditures. Governments subsidize private R&D because benefits often accrue to firms or persons who did not bear the costs of the R&D. The efficiency of R&D tax expenditures might be improved by providing relatively more support for R&D where the spill-over of benefits is likely to be larger.

For example, the current tax treatment for business spending on proprietary research is more generous than for business contributions to university-based research. Increasing tax incentives for donations supporting non-proprietary research would provide increased funds to universities and encourage much-needed interaction between businesses and the university research community. In 1982, only 0.2 per cent of the R&D performed by universities in Canada was funded by the business sector and 0.1 per cent of business-funded R&D was performed by universities. University-business collaboration was much stronger in the United States, where 3.0 per cent of university research was corporate-funded and 0.7 per cent of the R&D funded by business was university-performed.

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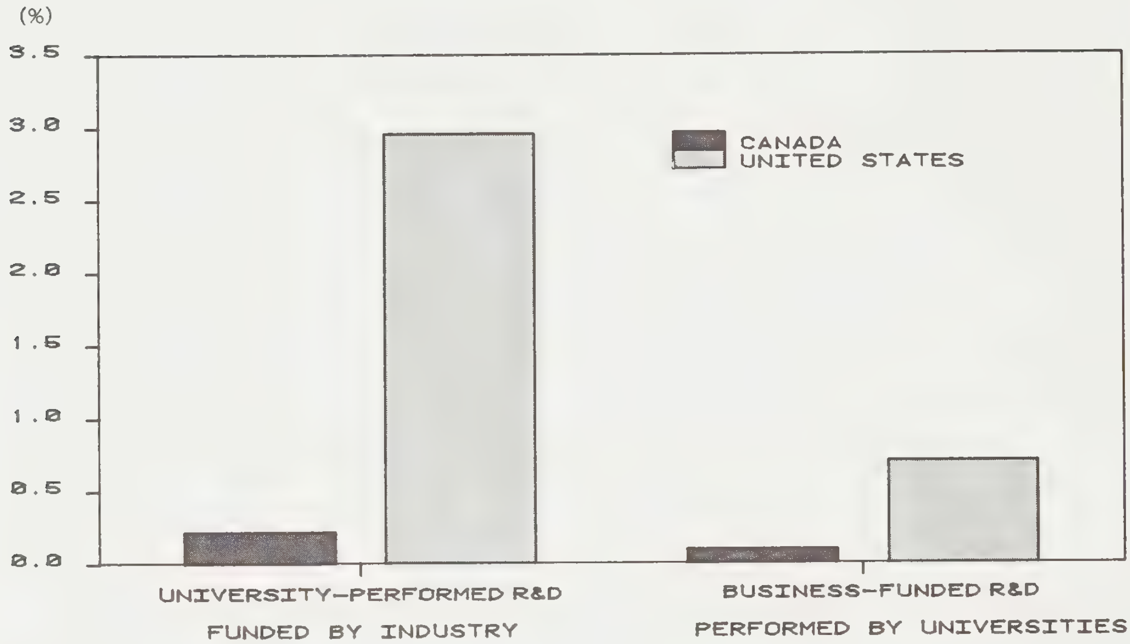
19 Ontario Budget Paper, R&D and Economic Development in Ontario: A Discussion Paper, 1983.

University and Industry R&D Collaboration
1982



Sources: Statistics Canada, R&D Expenditures in Canada, 1963-1982; National Science Foundation, National Patterns of Science and Technology Resources, 1982.

Recent developments in the United States and Japan have created renewed interest in the potential of R&D consortia. This approach is not new to Canada. The Pulp and Paper Research Institute of Canada (PAPRICAN) was founded in 1925. It is a non-profit research organization supported by nearly all pulp and paper companies in Canada and has close links to McGill University. The Institute's operating budget in 1982 was about \$15 million. In 1983, the federal government, under the Special Recovery Projects Program, allocated \$17 million to PAPRICAN for the construction of pulp and paper research facilities.

During the past decade, the Japanese Ministry of International Trade and Industry (MITI) coordinated eleven joint-venture R&D projects. In each case, the actual R&D was carried out by a consortium of industry participants, usually large corporations. The Flexible Manufacturing System Project, for example, involved 20 companies and total expenditures of \$66.9 million during the period 1977 to 1983.

These developments in Japan have provided a competitive impetus that is partly responsible for the recent formation of two research cooperatives in the United States. Under the auspices of the Semiconductor Industry Association, 18 major American companies, including IBM, Hewlett-Packard and Intel, have formed the Semiconductor Research Cooperative (SRC), which will fund university research. The SRC expects to spend $15 million (U.S.) in 1984 for research contracts with over two dozen universities. In comparison, the total spending on basic research in semi-conductor technologies by all American semiconductor companies was $20 million to $25 million (U.S.) in 1982. The second example of research cooperation is the Microelectronics Computer and Technology Corporation (MCC), formed by 13 major American computer firms, including Digital Equipment, Control Data, Honeywell, Motorola and RCA. Its mandate is to develop a broad base of fundamental technologies for use by members. MCC will have an annual budget of $75 million (U.S.) and will employ 300 to 400 people.

Research consortia reduce duplication in pre-competitive R&D and permit members to share results. From a public policy perspective, this represents an efficient use of R&D resources, and therefore public support for research consortia should be more generous than that provided for other private R&D. The federal government could remove a potential obstacle by clarifying the legality of cooperative R&D groups in its anti-combines legislation.

Industry Policies for Innovation

Technology development policies can include those that assist innovation directly, for example, policies involving government procurement of Canadian high-tech products, establishment of "innovation centres" and support of core companies in the high-tech industry in Ontario.

Government purchasing policies have been used to promote innovation. They do so in several ways. Government can be an informed and technically-demanding purchaser. If the purchase provides a larger cash flow, a procurement contract may be more valuable to a firm than a subsidy, particularly at the point when an innovation is introduced into the market. By purchasing an innovation, government provides the firm with a demonstration project to illustrate the

feasibility of the innovation. This can assist in later marketing of the innovation. The large volume of government purchases allows it to pool the risks involved in purchasing a number of different innovative products. A recently-published study of the contribution by governments to 52 industrial innovations in eight countries found that public procurement was, overall, the most important factor in the products' development[20].

One problem with this approach is that the discriminatory nature of procurement policies may provoke responses from our trading partners that would adversely affect our access to export markets. It would not be in the economic interests of Ontario or Canada to lose access to huge American public procurement markets as a consequence of providing domestic firms with preferential access to Canada's relatively small government purchases.

A possible compromise in the conflict between innovation and trade policy objectives is to focus procurement policy on small firms. This recognizes the fact that large corporations are better able to manage the financing, marketing and risks involved in innovation, and is also consistent with the long-standing preferences granted to small firms in American public purchasing policies.

The Ontario Government has established the Office of Procurement Policy to administer its 10 per cent Canadian Preference Policy. Ontario has also implemented the Industrial Development Review (IDR) procedure which permits an increased Canadian preference to be paid in the case of purchases identified as having the potential to stimulate new product innovation or other industrial development benefits.

Another approach to assisting innovation is to provide publicly-supported "innovation centres" to assist entrepreneurs in the commercialization of their inventions. One example is the Canadian Industrial Innovation Centre based at the University of Waterloo. The Innovation Centre offers a wide variety of business and technical support to individuals, including students and faculty, who are trying to commercialize their inventions. It gives students an opportunity to gain practical experience in applied research, development and management work. It also offers a comprehensive evaluation of the commercial viability of

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20 R. Rothwell and W. Zegveld, Industrial Innovation and Public Policy, 1981, p. 52-53.

an invention and assistance for technical development. Entrepreneurs receive financing aid and guidance in patenting, production licensing and financial planning. Most of the Centre's operating costs are currently met by federal government grants, although fees and shares in the equity or royalties derived from inventions should make it self-sufficient by 1990. Innovation Place Incorporated, a subsidiary of the Centre, serves as an incubator for fledgling firms, providing them with office space, office support functions and access to the full range of services outlined above. Since it opened in 1981, 24 high-tech firms have been launched from Waterloo's Innovation Place.

A number of American post-secondary institutions have innovation centres similar to the one at Waterloo. These include the Massachusetts Institute of Technology, Carnegie-Mellon University, the University of Oregon and Rensselaur Polytechnic Institute, a science and engineering school in New York State. By providing an impetus to innovative activity in their regions, these schools help to boost their local economies. Ontario could benefit from an increase in the number of facilities offering this type of nurturing environment to new businesses. A study recently announced by the Minister of Industry and Trade will examine the feasibility of establishing Innovation Places in a number of cities across the province.

New directions in industrial policy could include greater recognition of the role of "core companies" in developing an innovative and technologically up-to-date economy. Core companies have been defined as those "with the basic industrial and technological strength to act as the lead firm for a whole sub-industry of smaller companies"[21]. The basis for support of core companies is that they provide benefits to the economy which they cannot fully capture, such as training, R&D and stimulus to the development of component suppliers.

The Science Council of Canada has recommended supporting core companies to stimulate economic development in technology-based industries. The demands of the technologically-sophisticated large firms lead the suppliers to adopt state-of-the-art technology and become innovative. This pattern is evident in Canada's aerospace and telecommunications industries, where large core companies such as Spar and Northern Telecom have created a market for

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21 Science Council of Canada, Forging the Links: A Technology Policy for Canada, Report 29, 1979, p. 51.

high-technology electronic and engineering components. This has led to the development of a number of technologically-sophisticated subcontractors supplying core companies with highly specialized components.

The relationship between the core and supplier companies is mutually beneficial. The core company has technological depth -- as indicated by the tendency for larger companies to perform more R&D relative to sales -- and has the capacity to develop fully an innovative component within a larger system and to undertake widespread marketing, distribution and after-sales service, particularly in export markets. At the same time, core companies rely on innovative small firms to supply specialized components. Given this synergy, capital market and other support policies for small firms can contribute to a pattern of core company-supplier network development.

A number of policy approaches that have been used by governments have, to varying degrees, contributed to the emergence of core companies. These approaches include:

- pursuing freer international trade, either through the GATT or through sectoral arrangements such as the Auto Pact;
- encouraging multinationals to assign international product mandates, as Westinghouse has done, through selective subsidies and FIRA;
- compensating private sector companies for providing the benefits of core companies, such as training or R&D, as in the case of federal government assistance to Pratt and Whitney;
- sponsoring mergers in order to ease the adjustment leading to the emergence of a rationalized company such as the Canadian Appliance Manufacturing Company; and
- establishing a crown corporation or joint venture with the private sector, such as the biotechnology firm, Allelix.

Industry Policies for Diffusion

Government policies to stimulate technical advance in Canada have generally taken the form of assistance to R&D and, to a lesser extent, innovation. Policies to promote diffusion have received little attention. This is because it is less apparent that diffusion activities are subject to the same

extent of market failure as R&D. In a recent report, however, the Economic Council of Canada concluded that a moderately strong case can be made for government assistance of diffusion[22].

One characteristic of the diffusion process is that uncertainty is reduced as the experience of early adopters is observed. In this way, early adopters provide a service to other firms for which they are not compensated. Government support of early adoption recognizes the value of these external benefits. In addition, there appear to be economies of scale in gathering and disseminating information about new products and processes. An independent government agency may be a natural candidate for the large-scale provision of technological information, in part because it may be seen to be more objective than sources with a direct interest in particular technologies.

Ontario's Technology Program is a rare example of a major government expenditure to aid technological diffusion. This program includes six technology centres for which the Government is providing a total of $100 million over five years. The main purpose of the program is to provide small firms with information on technology that is currently available. Further initiatives to encourage the diffusion of new technology could include:

- establishing new technology centres, as proposed by the private sector, aimed at the transfer of new technologies and associated management practices;
- developing a program for the shared-cost funding of process technology demonstration projects; and
- undertaking a new program to encourage leasing of advanced-technology equipment.

The first of these possible initiatives would rely on private companies, industry associations and communities to identify the required industry or technology focus and location. Recommendations could be received from any sector, including the service industries. This approach introduces an important "market test" into any expansion of the program.

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22 Economic Council of Canada, The Bottom Line: Technology, Trade, and Income Growth, 1983, p. 33.

The second possible approach could involve shared-cost demonstration projects. For example, a recent federal/provincial program involved the funding and management of demonstration projects relating to energy conservation, and the transfer of information about the demonstration experience to potential users. It translated technologies, techniques and systems into real-life situations and contributed to their widespread acceptance.

This type of program could be designed for robotics technology, for example, where implementation of a particular production system could be demonstrated in a small factory setting. By locating demonstration projects in different industries and regions, the program could increase information on, and reduce risks from, the adoption of new technology.

The third option draws on the experience of Japan, where government-sponsored robot-leasing and computer-leasing companies have assisted the growth of Japanese producers and accelerated the diffusion of these technologies. With the cooperation of the private sector, leasing or time-sharing arrangements could be established for small firms. Leasing arrangements would enable a firm to return equipment if it proved to be inappropriate. A sizeable program of advanced-technology leasing would also minimize the retarding effect on diffusion of thin resale markets for used equipment. Further, the introduction of state-of-the-art equipment into firms could be an effective way of encouraging them to undertake training.

Another approach to encouraging diffusion was proposed by the Ontario Microelectronics Task Force[23]. It recommended that the costs of purchasing foreign technology through licencing be made eligible for federal and provincial support programs on a selective basis. The Task Force noted that imported technology can supplement a firm's existing capacities and serve as a springboard for further development.

It should be noted that when a firm incorporates a licenced technology into its product or process, it may provide other firms with beneficial information, for which it is not compensated. Therefore, public support for the costs of non-exclusive licences for relatively new technologies with widespread application could be considered.

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23 Microelectronics: Report of the Task Force to the Government of Ontario, October 1981.

Finally, Canada's patent system appears to be an underutilized source of technological information. Patent descriptions can help in technical problem-solving and in generating ideas. They can also inform firms where expertise may be available in a particular area, thereby promoting technology transfer. The Economic Council of Canada has recently drawn attention to the enormous differences between countries in the extent to which patent information is actively disseminated. Japan is the most active in encouraging and facilitating the use of patent information, while Canada is one of the least active among developed countries. The Economic Council of Canada recommended that the Patent Act be amended to give the Patent Office a mandate to establish a patent technical-information service[24].

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24 Economic Council of Canada, The Bottom Line: Technology, Trade, and Income Growth, 1983, p. 83.

VI CONCLUSION

An accelerating pace of technological change, the growing domination of standardized-technology manufacturing and resource production by less-developed countries, and continuing competition from other advanced countries are transforming the economies of Canada and Ontario. Innovation and advanced-technology application will be key to providing knowledge-intensive and skill-intensive employment that is well paid yet internationally competitive. These developments suggest that government should review its policies to ensure that Ontario's potential for advanced-technology development is enhanced, not inhibited.

The approach of the Ontario Government is to rely on market forces, combined with supportive actions by Government, to shape the economic transformation. In general, individuals and firms are in the best position to assess their own capacities and respond to needs signalled by the market. Governments must supplement market forces -- more so, perhaps, in matters relating to technical advance than in other areas of economic development. Government assistance is warranted in education, training, research and development, and venture capital. It is also sometimes worthwhile for governments to encourage the linkages that develop as a result of supporting emerging technologies or potential "core companies". Finally, in designing macroeconomic and structural policies, including those relating to market size and foreign ownership, government should be sensitive to the impact of these policies on innovation and diffusion.

Given this strategic approach to technology-based economic development, a wide range of specific policies should be considered. This discussion paper has reviewed current policies and identified a number of options consistent with the Province's broad strategy. Its objective is to encourage public debate.

APPENDICES

APPENDIX A
GLOSSARY OF TERMS

Computer-aided design/Computer-aided manufacturing (CAD/CAM): Computer-aided design involves the use of computers for graphics, modelling and simulation of designs for production. Computer-aided manufacturing involves the use of computers and numerical control equipment to carry out manufacturing processes.

Diffusion: Diffusion refers to the adoption of a new process or imitation of a new product after it has been commercialized.

Economies of scale: Economies of scale are reductions in the average cost of production achieved by increasing the volume of output, thus using machinery and labour more efficiently.

Export orientation: An industry's export orientation is the ratio of the value of goods exported to the total value of shipments made by firms in the industry.

External benefits: External benefits arise when the actions of a firm or individual result in free favourable effects for other firms or individuals. For example, a firm's innovative activity gives rise to external benefits if its innovation is copied inexpensively by competitors. Similarly, a firm's training program creates external benefits if its employees are hired away by competitors.

High-tech manufacturing: The high-tech manufacturing sector is defined in this paper to include eight industries: pharmaceuticals and medicines, communications equipment, aircraft and aircraft parts industries, office and store machinery manufacturing, electrical industrial equipment, industrial chemicals, plastics compounds and synthetic resins, and scientific and professional equipment.

Import penetration: Import penetration is the ratio of the value of goods imported to the total value of purchases made.

Innovation: Technological innovation is the commercialization of a new or improved product or processing technique. Innovative activities occur after the R&D stage and include design and engineering, and manufacturing and marketing start-up. The term also refers to the new product or process itself.

International Product Mandate: An international product mandate assigns total responsibility for particular products to an affiliate of a multinational corporation. This implies responsibility for research and development, manufacturing and international marketing. The term is also often used to refer to a less complete assignment of responsibilities.

Knowledge-intensive industry: A knowledge-intensive industry is one that makes heavy use of skilled labour and educated personnel, relative to its use of other inputs, such as unskilled labour and equipment.

Research and development (R&D): Research includes both basic research: the advancement of scientific knowledge without a specific practical application in view; and applied research: the advancement of knowledge with a specific practical application in view. Development is the use of the results of basic or applied research to create new or improved materials, devices, products or processes.

R&D-intensive industry: An R&D-intensive industry is one that performs a large amount of research and development relative to its size. The R&D intensity of an industry is calculated as the ratio of its R&D expenditures to its value-added or sales.

Technological opportunity: Technological opportunity is the scope for technology-based innovation. It is related to the growth of scientific knowledge that is relevant to the industry, and is usually measured by the R&D intensity of the industry.

Value-added: Value-added is the actual value of work carried out in a particular industry. It is the difference between an industry's total revenue and the costs of the materials, parts and purchased services used in producing goods and services.

APPENDIX B
CURRENT ONTARIO PROGRAMS FOR INNOVATION AND DIFFUSION

Human Resources: Education and Training

- In fiscal year 1983-84, Provincial funding for operating grants, capital grants and BILD programs to support post-secondary institutions totalled \$2.5 billion.

- **Ontario Training Incentive Program.** OTIP (long-term) provides incentives to employers and employees to encourage long-term on-the-job training. OTIP (short-term) provides unemployed workers with a combination of training and employment. (\$6.0 million.)

- **Employer Sponsored Training.** EST provides support funding for Community Industrial Training Committees to facilitate the involvement of government, employers, community colleges and unions in identifying skill requirements at the local level. (\$3.4 million.)

- **Training in Business and Industry.** TIBI II and TIBI III assist employers and employees in preparing for the implementation of advanced technology. (\$9.4 million.)

R&D Funding

- The Ontario Research Foundation specializes in industrial problem-solving through the provision of technical services, including R&D, to small firms on a contractual basis. (\$4.1 million.)

- BILD has provided matching grants to 11 universities for research contracts received from the private sector. (\$4.3 million.)

- Ontario Government current R&D expenditures by performer is shown in Table A.

GOVERNMENT OF ONTARIO CURRENT R&D EXPENDITURES, BY PERFORMER

Table A

Performer	1974-75 $000	1974-75 %	1981-82 $000	1981-82 %
Intramural	17,308	47.4	31,978	40.3
Industry	311	0.9	9,439	11.9
Universities	11,523	31.6	24,435	30.8
Hospitals and Health Organizations	3,341	9.2	7,920	10.0
Ontario Research Foundation	2,630	7.2	4,123	5.2
Other	1,372	3.8	1,541	1.9
Total	36,485	100.0	79,436	100.0

Note: Table shows Government of Ontario current R&D in the natural sciences and engineering. Includes in-house expenditures and extramural contracts, grants and research fellowships. Columns may not sum due to rounding.

Source: Statistics Canada, Scientific Activities of the Government of Ontario, Fiscal Year 1981-82, 1982.

Capital Markets

- **Small Business Development Corporations Program.** SBDCs, introduced in the 1979 Ontario Budget, provide incentives to assist equity investment in small businesses. This program is not restricted to technology-based firms.

- **Ontario Development Corporations.** ODC administers the High Technology Loan Program for small Canadian companies. The three Ontario Development Corporations provide additional loans and loan guarantees to non-technology-based small firms.

- **IDEA Corporation.** IDEA was established to encourage and finance technological innovation.

Industry Policies for Innovation and Diffusion

. **Assisting Innovation.** The Ontario government provides targetted assistance to innovation projects through BILD. These projects include:

- Telidon: Teliguide;
- Institute for Hydrogen Systems;
- Ontario Centre for Remote Sensing;
- Transit Information, Communication and Control Systems;
- Canadian Educational Microcomputer; and
- Exploration Technology Development Fund.

. **Assisting Innovative Small Business.** The Ontario Government, through the Ministry of Industry and Trade, provides programs to assist small businesses during various stages of the innovative process.

. **Assisting Innovation through Government Investment.** Government equity investment has been used to promote some innovative sectors. Ontario Hydro, Urban Transit Development Corporation and Allelix are all major corporate entities in their respective industries.

. **Assisting Diffusion through Technology Centres.** The Ontario Government assists the diffusion of technologies through the Ontario Technology Program. Six technology centres are directed towards particular technologies and industries, and are dispersed throughout the province as follows:

- Ontario Centre for Microelectronics, Ottawa;
- Ontario Centre for Advanced Manufacturing - Robotics, Peterborough;
- Ontario Centre for Advanced Manufacturing - CAD/CAM, Cambridge;
- Ontario Centre for Resource Machinery, Sudbury;
- Ontario Centre for Farm Machinery and Food Processing, Chatham; and
- Ontario Centre for Automotive Parts, St. Catharines.